Oak Ridge National Laboratory

Introduction to Lustre I/O at NCCS

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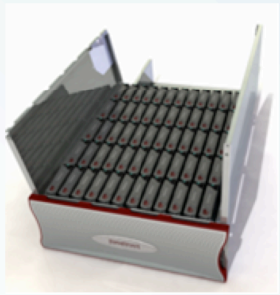
Spider, the OLCF center-wide file system



"Spider" provides a shared, parallel file system for all systems
- Based on Lustre file system

Demonstrated bandwidth of over 240 GB/s

Over 10 PB of RAID-6 Capacity
- 13,440 1 TB SATA Drives

192 Storage servers
- 3 Terabytes of memory

Available from all systems via our high-performance scalable I/O network
- Over 3,000 InfiniBand ports
- Over 3 miles of cables
- Scales as storage grows

Benefits of Spider

- Accessible from all major OLCF systems
  - Avoids data “islands”
  - No need to transfer data from simulation system to analysis system
    - Breaks the speed barrier of LAN transfers
  - Can use dedicated nodes to do WAN transfers
    - More friendly to your fellow users
    - Less likely to be caught by a system interrupt
- Accessible during maintenance windows
  - Spider remains accessible when Jaguar and JaguarPF are down
  - You can still get to your data!

Benefits of Spider (Continued)

- Unswept project spaces
  - 1 TB of space available for each project
  - Not backed up – use HPSS
- Higher performance HPSS transfers
  - XT Login nodes no longer the bottleneck

Drawbacks of Spider

- It's not all wine and roses – more like an expedition
- No one has run at this scale before
  - Spider is the largest, fastest Lustre file system in the world
- Activity on other systems can interact with your IO
- Tuning your use is important
- Pathological file system use can make for a bad day
  - We're working to find and help correct misbehaving applications
- We're all in this together – your help is appreciated

Quota policy

Area	Path	Quota	Swept?	Backups?	Purge Policy
Home Directory	/ccs/home/$USER	5 GB	No	Yes	1 month post-user
NFS Project	/ccs/proj/$PROJ	50 GB	No	Yes	1 month post-project
Lustre Project	/tmp/proj/$PROJ	1000 GB	No	No	1 month post-project
Spider Scratch	/tmp/work/$USER	None	14 days	No	1 month post-user
Local Scratch	varies by system	None	14 days	No	1 month post-user
HPSS Home	/home/$USER	2 TB 200 Files	-	-	3 months post-user
HPSS Project	/proj/$PROJ	45 TB 4500 Files	-	-	3 months post-project

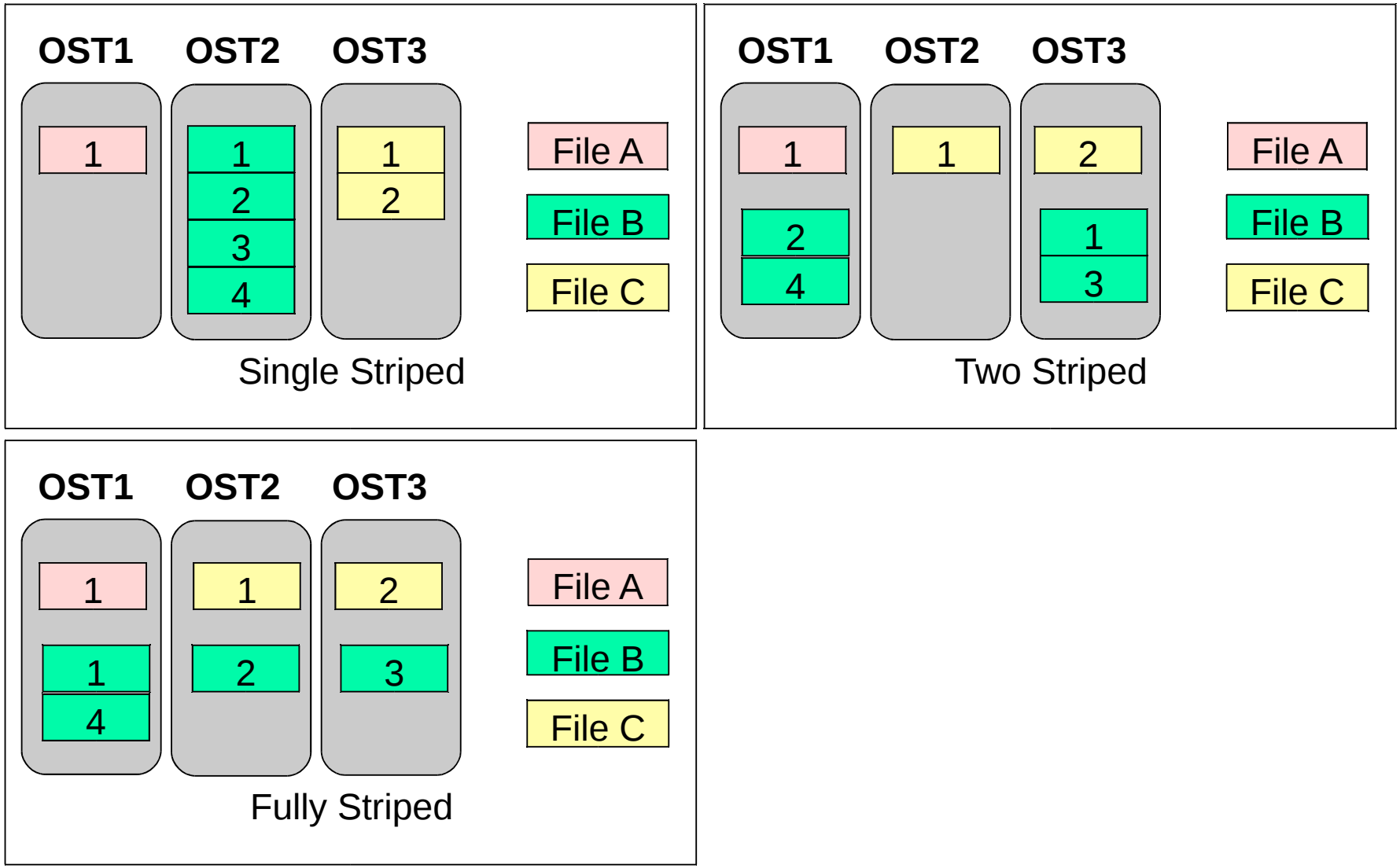
Requesting a File System on Spider

- Spider currently contains three storage areas (widow1, widow2, widow3)
- When you submit a job, you can request to run through filesystem maintenance.
  - `qsub -l gres=widow2`

Lustre concepts

- Two types of servers
  - Metadata server (MDS)
    - Holds the directory tree
    - Stores metadata about each file (except for size)
    - Once file is opened, I/O to file does not involve the MDS
  - Object storage server (OSS)
    - Manages OSTs (think single disk/LUN)
    - OSTs hold stripes of the file contents
      - Think RAID0
    - Maintains the locking for the file contents it is responsible for

Lustre concepts (striping)



Lustre Best Practices (User)

- Use `lfs setstripe` in a safe manner
- Set striping appropriately for your use
- Choose stripe width for your application
- Avoid excessively large numbers of files in directories
- Avoid using `ls -l` repeatedly
- More information on website

  http://www.nccs.gov/user-support/general-support/file-systems/spider

Lustre Best Practices (User)

- Use `lfs setstripe` in a safe manner
  - Always use the explicit options, not the positional ones
  - Avoid specifying a starting OST index
  - Use `-s` for stripe width (default is 1MB)
    - Can specify in bytes, kilobytes (k), megabytes (m), or gigabytes (g)
  - Use `-c` for stripe count (default is 4)
  - Not specifying an option keeps the current value
- Bad:

```
lfs setstripe $NAME 1m -1 16
```

- Good:

```
lfs setstripe $NAME -s 1m -c 16
```

Lustre Best Practices (User)

- Use `lfs getstripe` to check the striping on a file
- Example: extracting source code

```
# mkdir source
# lfs setstripe source -c 1
# cd source
# tar -x -f $TARFILE
```

- Example: fixing incorrect striping

```
# lfs setstripe newfile -c 16
# cp oldfile newfile
# rm oldfile
# mv newfile oldfile
```

Lustre Best Practices (User)

- Set striping appropriately for your use
  - Default stripe count is 4, but may not match your usage
  - Small files (< 250 MB) should use a single stripe
  - Large files accessed in parallel (single shared-file) should have a stripe count that is a factor of the number of writers (e.g. 20 vs 21 for 400 writers)
  - Cannot use more than 160 stripes currently

Lustre Best Practices (User)

- For single shared-file, choose per-writer data size as stripe width if possible
  - If each rank will write 256 MB, then use 256 MB as the stripe width
  - Minimizes lock contention
  - Liaison can help determine best stripe size
  - May not always be possible to pick a winner

Lustre Best Practices (User)

- Avoid directories with excessive numbers of files in them
  - Excessive is a fuzzy number
  - > 1M definitely excessive
  - 100k probably excessive
  - 50k borderline
  - 10k sure, why not?

Lustre Best Practices (User)

- Avoid doing `ls -l` repeatedly
  - Especially in an excessively large directory!
  - If you are just looking to see if a file exists, use plain `ls`
  - Better yet – look for that file explicitly
  - Avoid options that sort by time stamp or add color to the listing

Lustre Best Practices (Developer)

- Open files read-only when possible
- Read small, shared files once
- Use a directory hierarchy to limit files in a single directory
- Use access(), not stat() to check for existence
- Avoid flock()
- Consider using libLUT or middleware I/O libraries
- Stripe-align I/O if possible

Lustre Best Practices (Developer)

- Open files read-only when possible
  - Fortran defaults to READWRITE if no ACTION is given
  - Fortran adds O_CREAT if opening file for writing
- O_CREAT requests an exclusive lock for the file (not contents)
  - Lock ping-pong championships when large job opens the file from all ranks at once

Lustre Best Practices (Developer)

- If all ranks need data from a single file, it is better to broadcast the contents than have everyone read it

  Fortran example, sans error handling and assuming known file size:

```
CALL MPI_COMM_RANK(MPI_COMM_WORLD, my_rank, ierr)
IF (my_rank .eq. 0) THEN
    OPEN(UNIT=1,FILE=PathName,ACTION='READ')
    READ(1,*) buffer
ENDIF
CALL MPI_BCAST(buffer, SIZE, MPI_CHAR, 0,
                MPI_COMM_WORLD, ierr)
```

Lustre Best Practices (Developer)

- Use a directory hierarchy to limit files in a single directory
  - Opening a file currently keeps a lock on the parent directory for one message round-trip
  - Split directories up to avoid contention
  - For a two level hierarchy, square root of the total number of files provides best balance

Lustre Best Practices (Developer)

- Use access(), not stat() to check for existence
  - Size is not kept on metadata server, so using stat() requires communication with each object storage server that has a portion of the file
  - access() only needs one request

Lustre Best Practices (Developer)

- Avoid flock()
  - O(N**2) algorithm for number of lockers on file
  - Ok, if N is small
  - Does not scale to systems the size of Jaguar or JaguarPF

Lustre Best Practices (Developer)

- Consider using libLUT or middleware I/O libraries such as ADIOS
  - Extracting full performance from the file system requires knowledge of the environment
  - Maintaining performance during concurrent access from other users requires constant adaptation
  - Do you really want to write all of this?
  - And maintain it for multiple systems?

Lustre Best Practices (Developer)

- Stripe-align I/O if possible
  - Lustre is a POSIX-compliant file system
  - Overlapping writes are 'last-to-write wins'
  - This requires locking of the contents
  - Unaligned writes require obtaining locks from multiple servers

Protecting your data (HPSS)

- High Performance Storage System
- Accessible from all login nodes
- Accessible from data transfer nodes
- Over 8.2 PB storage in 16.5 M files stored
- Scratch storage space is just that
- If you care about your data, put it in HPSS
- Once copy of data is default, more can be requested

Using HPSS

- HSI
  - easy to use (FTP-like interface)
  - fine-grained control of parameters
  - works well for small numbers of large files
- HTAR
  - works like tar command
  - treats all files in the transfer as one file in HPSS
  - preferred way to handle large number of small files
- More information on OLCF website

  http://www.nccs.gov/computing-resources/hpss/use

HPSS Best Practices

- If you care about your data, put it in HPSS
- When possible, consider transferring your files from the compute job (needs keytab access)
- Try to combine small files into larger ones
- Respect your fellow users – don't spawn large number of transfer processes on the login nodes
- Avoid needing to change the COS (expensive!) by letting the tools read from disk rather than streaming the output of a command